

FINAL TECHNICAL REPORT

AWARD NO: 00HQGR0008

Recipient Name: The University of Memphis, Center for
Earthquake Research and Information

PI Name: Gary Patterson

Title of Recipient's
Application: Strategies for Mid America Residential
Retrofit

Program Element: Education and Outreach

ABSTRACT

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Strategies for Mid America Residential Retrofit

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Central US seismic hazard has been a research focus of the National Earthquake Hazard Reduction Plan for many years. Significant advances have been made to better understand geotechnical, geophysical, and seismological characteristics that influence losses related to damaging earthquakes in the New Madrid, Wabash, and East Tennessee seismic zones, but awareness lags behind due to a paucity of damaging events in the last 200 years. Some Central US states, such as Tennessee, have recently adopted seismic building codes, but the vast majority of residential structures in the Central and Eastern U.S. were not designed to resist significant horizontal forces from wind or earthquake. Earthquake retrofit guidelines for residential structures, considering many different construction methods, have been developed and distributed in the western United States where earthquakes occur more frequently, but little retrofit information has been developed within the context of Central U.S. seismic hazard to allow homeowners to make cost beneficial decisions. This project provides a system of information transfer to address this need. A significant outcome of this project is identification of specific differences in historical residential construction methods between the Eastern US and the Western U.S., which significantly impacts our ability to apply previously developed retrofit standards uniformly across the nation, especially for pre 1940's structures.

INTRODUCTION

Earthquake retrofit standards have been developed and refined in the western U.S. as a result of frequent damaging earthquakes with the proactive support of local, state, and federal government in collaboration with private-sector interests and academia. This project, Strategies for Mid America Residential Retrofit (SMARRT), provides comprehensive retrofit information within the context of Central US earthquake hazard to allow homeowners the ability to weigh retrofit costs against the risks associated with regional seismic sources. SMARRT is a system of information transfer that provides proven retrofit strategies related to many different modern and historical construction styles that is accessible from a single source. The system includes several elements: a high quality trade show display to educate Central U.S. contractors and homebuilders; a website with comprehensive information based on experience data, and; hardcopy brochures to guide users to the SMARRT website.

Cost benefit and seismic retrofit in areas of infrequent seismicity

Residential seismic retrofit primarily entails structural modifications to provide a continuous load path throughout the structure and non-structural modifications to strengthen other heavy components that could cause loss of life and significant property damage. Structural modifications call for strengthening connections between the foundation and the load bearing walls, the walls and the ceiling joists and/or rafters, installation of collar beams to prevent roof peak separation, and strengthening walls and corners near large openings. Non-

structural modifications strengthen heavy unreinforced elements, such as chimneys and water heaters. Unless the homeowner's perception of risk merits it, or major remodeling upgrades are also planned in tandem, complete seismic retrofit may not cost effective in areas of infrequent seismicity, and in some cases may approach the total value of the structure. However; in some cases a limited retrofit strategy can be applied to address the most common or expensive potential damages based on the specific construction methods used in any given residential structure.

Important project collaborations: East meets West

The PI for the project initially collaborated with the University of Washington and the Seattle Project Impact Team, which had implemented a comprehensive program to train homeowners and contractors to cost-effectively retrofit homes. The PI attended Home Retrofit classes organized by the Seattle Project Impact Team, which had already considered and integrated the most prominent retrofit guides from California. Seattle's Home Retrofit Project also developed a process that allows homeowners to understand if their home, based on its construction method, could be retrofitted economically. The classes were sponsored by the Simpson Strong Tie company, a major manufacturer of seismic/wind retrofit components in the U.S., and State Farm Insurance with significant logistical support from the University of Washington and community outreach elements of the Pacific Northwest Seismology Lab (Bill Steele). This was a unique opportunity to discuss retrofit strategies with a well-informed multidisciplinary group of researchers, urban planners, and public communications specialists.

The PI also met with the Director of Engineering and Vice President of the Institute for Business and Home Safety, Tim Reinhold, on several occasions to discuss various retrofit and new construction safety programs as they related to this NEHRP project. As a result of this collaboration, *the PI has been invited to present results from this NEHRP project as a panelist and speaker at the National IBHS Conference on November 13 and 14, 2008 in Tampa Florida.* As suggested by David Applegate, the PI also collaborated with the USGS, Federal Emergency Management Agency, The Western States Seismic Policy Council, The Consortium of Universities for Research in Earthquake Engineering, The Southern California Earthquake Consortium, and other members of the Earthquake Country Alliance to better integrate new retrofit information from California. Publications from these organizations are downloadable from the project website.

CHALLENGES, PROJECT DEVELOPMENT, AND PRODUCTS

The PI for SMARRT was uniquely suited to address this project with a background in seismic hazard assessment, geology, Central US seismic hazard, and former residential remodeling contractor in Memphis, Tennessee. The primary source of information for determining the vulnerability of residential structures to earthquake damage was *Earthquake Losses to Single-Family Dwellings: California Experience*, US Geological Survey Bulletin 1339-A, 1990. Although site specific geologic effects and proximity to primary fault face rupture were not differentiated from damage due to strong ground motion in this bulletin, the document provides a

comprehensive look at residential losses resulting from earthquakes that have occurred in the Western U.S. since 1971.

Basic differences in construction practices between the East and West

Many different residential construction styles have evolved over the last 200 years in the US such as unreinforced masonry, solid-pour conventional foundation, post and beam conventional foundations, cinder block conventional foundation, slab construction, etc. Each of these methods is unique with respect to horizontal force resistance; therefore there is no single retrofit strategy that will work for all homes. Additionally, each structure's actual exposure to earthquake losses is variable and each homeowner has different perceptions of the risk and different levels of disposable income. Therefore, the cost beneficial nature of retrofitting residential structures to mitigate earthquake damage is a personal decision and is complicated by numerous retrofit applications and construction styles noted above. It was a challenge to address these important differences through collaboration with NEHRP to modify the project scope to appropriately address the stated goals.

It became apparent in the initial phases of the project that a significant amount of the retrofit information had been developed in the western U.S. to address certain residential construction styles that are rarely utilized in the Central U.S. Many of the pre-1940 wood frame residential structures in California utilize post and beam foundations with exterior knee-walls extending from the foundation footing to the base plate of the first story wall. Foundations with knee walls (also known as "pony walls" or "cripple walls") provide a significant weakness at the base

of the structure that is very susceptible to damage from earthquakes and has been a major focus of western U.S. retrofit manuals. The presence of knee wall foundations does not necessarily cause total collapse but the cost of repairs can be very high because water, sewer and electrical connections are easily broken and the home must be lifted and placed back on the repaired foundation. Perhaps one of the most important findings of this project is that pre-1940 homes in the Central U.S. with conventional foundations were commonly constructed with a monolithic, solid-pour concrete footing wall with no cripple walls. As identified by Seattle's Home Retrofit Project, these types of structures can be retrofitted economically to address the most common type of earthquake damage. Of course it is preferable to retrofit all joints that provide continuous load path (footing to foundation, walls to ceiling joists, roof peak, etc) but addressing weak connections at the foundation/sill plate level can prevent costly repairs due to a shift of a few inches off the foundation.

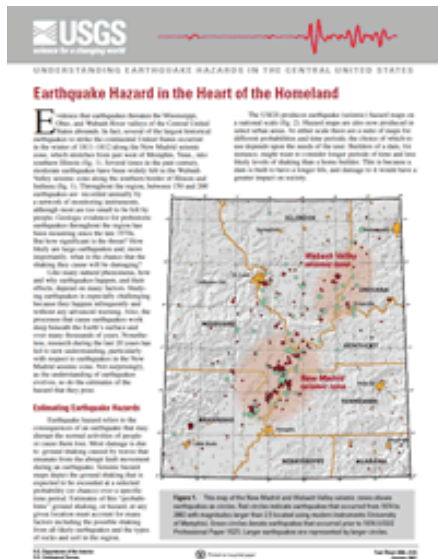
Comprehensive information via the Internet

As the project developed it also became apparent that comprehensive retrofit information addressing various construction styles would call for transfer of hundreds of pages of information to users spread out over the entire Central U.S. The project evolved to address these constraints through the development of a "Residential Retrofit Info" website at <http://itmattersareyouprepared.org/residentialretrofitinfo.html> and supplemented with a brochure to introduce the project concept and guide users to internet-based information. The project website contains links to CERI information pages and

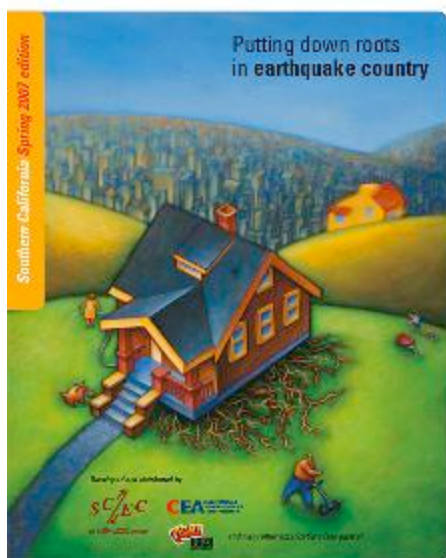
downloadable retrofit information products to provide background on earthquake hazard in the Central U.S.

The following retrofit documents are downloadable from the SMARRT project website, [Residential Retrofit Info:](#)

Earthquake Hazard in the Heart of the Homeland. US Geological Survey Factsheet



Putting Down Roots in Earthquake Country. The Southern California Earthquake Center and the Earthquake Country Consortium



Seattle Project Impact Home Retrofit Series Overview and Retrofit Definitions. Seattle Project Impact Consortium

Guide to Completing the Home Assessment Checklist. Home Earthquake Retrofit Series, Seattle Project Impact Consortium

Guide to Completing an Earthquake Retrofit Plan for Wood-Frame Residential Buildings. Seattle Project Impact Permitting and Standards Committee

Bracing for the Big One: Retrofit Guide for Historic Homes. Utah Department of State History

How the City of San Leandro can help you strengthen your home for the next big earthquake in the Bay Area, Prescriptive Seismic Strengthening Plan for Light Wood Frame Residential Structures. City of San Leandro, California

Homebuilder's Guide to Earthquake Resistant Design and Construction, Federal Emergency Management Agency Document 232

Earthquake Home Hazard Hunt Poster, FEMA and NEHRP

Digital Video Shake Table Demonstrations:

Large-Scale Shake Table Testing of Wood Frame Residential Structures and Contents, Consortium of Universities for Research in Earthquake Engineering (CUREE)-Caltech Wood Frame Project. (Multiple views)

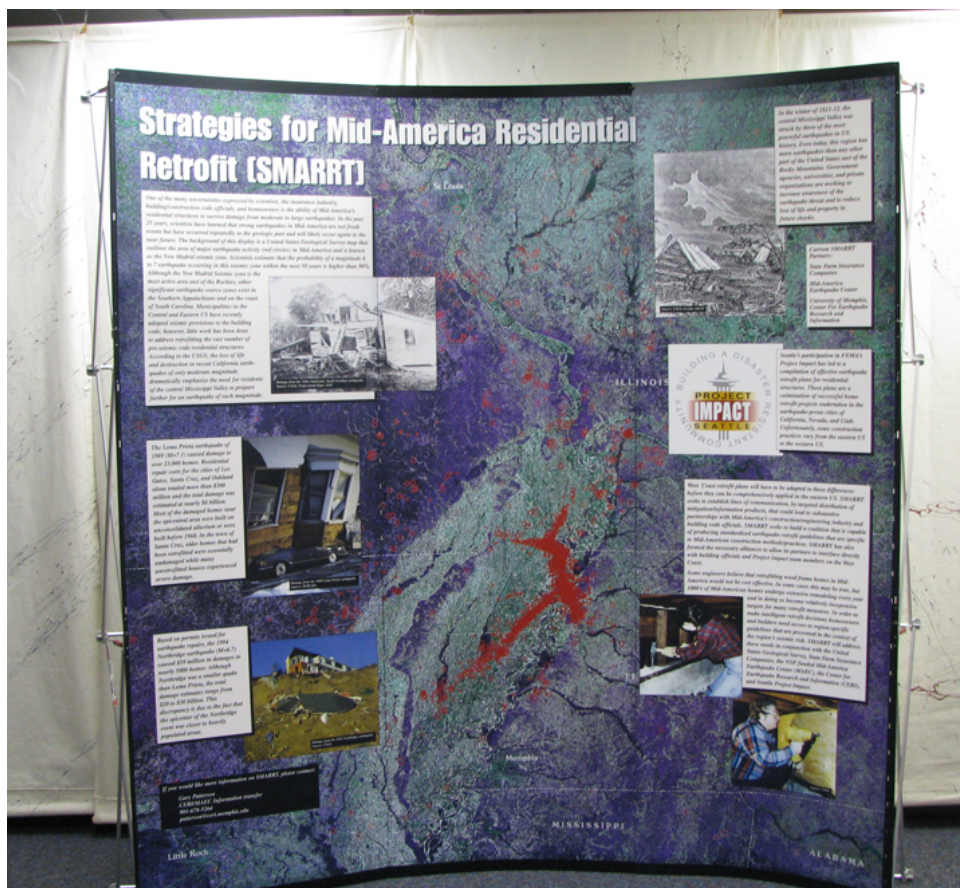
Virtual Building Retrofit Demonstration, Brad Cross and Scott Smith, Southern Illinois University at Edwardsville.

Retrofit visualization

Another phase of the original project was to interactively demonstrate retrofit measures that specifically address pre-1940 construction methods in the Central U.S. The PI collaborated with the Electrical Engineering Department of the University of Southern Illinois at Edwardsville (Brad Cross and Scott Smith) to

produce a digital visualization of the retrofit process for solid-pour conventional foundation residential structures (including chimney and water heater retrofit) that is displayed on the project website. The visualization is part of a larger Virtual Reality Modeling Language (VRML) project funded by the Mid America Earthquake Center that interactively allows users to generate earthquakes of various sizes and test different retrofit strategies. Unfortunately the VRML has been changed to "X3d" format, which could not be integrated as an online, interactive visualization tool without significant additional resources. However, the PI continues to collaborate with SIU Edwardsville to formulate future applications.

SMARTT tradeshow display and brochure



The SMARRT tradeshow display increases awareness of retrofit options to homeowners, homebuilders, and insurers within the context of Central US earthquake hazards. The project brochure utilizes the same information and artwork to guide users to products on the project website. The PI will exhibit SMARRT materials at the 2008 National Conference of the Institute for Business and Home Safety at the request and expense of IBHS. This recognition of the importance of the project by IBHS represents a capstone for the effort and acknowledgement of NEHRP Outreach products.